The Spread of Non-native Plant Species Collection of Cibodas Botanical Garden into Mt. Gede Pangrango National Park

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ABSTRACT

The role of botanic garden in spread of invasive alien plant species has concerned of international worldwide. The aim of this research was to study the extent to which non-native plant species from Cibodas Botanical Garden (CBG) invades into natural rainforest of Mt. Gede Pangrango National Park that adjacent CBG. A line transect was made edge-to-interior with 1600 m in distance from CBG boundary. Result showed that distance from CBG was not significant in correlation with tree and tree-let non-native density. Furthermore, presence of existing CBG's plant collection irregularly responsible for spread of non-native species into natural forest. Three invasive species (*Cinchona pubescens*, *Calliandra calothyrsus*, and *Cestrum aurantiacum*) possibly were escape from CBG and it showed edge-to-interior in stems density. The patterns of other species were influenced by presence of ditch across transect (*Brugmansia candida* and *Solanum torvum*), transect location along human trail which facilitate *Austroeupatorium inulifolium* spread into interior forest, and another non-native species (*Solanum macranthum* and *Toona sinensis*) did not have general pattern of spread distribution. Overall, botanical gardens should minimize the risk of unintentional introduced plant by perform site-specific risk assessment.

Keywords: *invasive alien species, non-native species, distance, forest edge, Cibodas Botanical Garden*

INTRODUCTION

Botanical gardens are recognized as the last defense in plant conservation through their living collections and data record of threatened and economic valued species, taxonomic and plant propagation research, public environmental education, and additional purpose as recreation area [1]. However, establishment of botanical gardens in the tropics at 18th and 19th century droved by competition of colonial powers in trade and commerce of economically important products [2, 3]. Large number of introduced plant collection of botanic garden might have in both deliberate and accidental introduction of invasive alien plants across the globe [2, 4, 5].

Species with native ranges centered in the tropics and with larger seeds were more likely to regenerate, whereas naturalization success was explained by longer residence time, faster growth rate, fewer seeds per fruit, smaller seed mass, shade tolerance, high competitive abilities, and alellopathy [6, 7]. The introduction of non-native plants may alter the availability of resources critical for establishment, growth, and reproduction of native species [8].

Various researches were conduct due to spread of invasive plants from botanical gardens. Over half of all naturalized and spreading species were observed in forest fragments and edges came from Amani Botanical Garden collection [2]. A single individual of *Miconia calvescens* was planted at Harold L. Lyon Arboretum, Hawaiian Island in 1964. That was contributed to subsequent naturalized seedlings were first noted in 1975 and continue to be reported to the present [9]. *Lantana camara* was introduced in 1809 at Calcutta Botanical Garden from Srilanka as ornamental plants. Because of its prolific seed production, it escaped to cultivated land and by 1941 it has become a serious weed on 4000 ha in pastures, wastelands, road sides, and forests replacing local vegetation in most parts of India [10]. Case studies above suggest that botanical gardens face challenges in managing their living collections to prevent plant invasions [4].

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Significant number of plant collection in Cibodas Botanical Garden (CBG) is non-native species (42 % total collection). Previous study reported 10 exotic species was escape from CBG into secondary remnant forest inside the garden [11]. Natural forest as a nearby area adjacent with CBG posed high risk of spreading non-invasive species unintentionally. This study was aimed to study the extent to which non-native plant species from CBG invades into natural rainforest of Mt. Gede Pangrango National Park that adjoining CBG.

MATERIALS AND METHODS

Study site

The study was conduct on October 2011 at adjacent forest of CBG. Forest study is under territory Management of Mt. Gede Pangrango National Park and was located at 6°44'714''-6°45'229'' S and 107°00'368''-106°59'813'' E with elevation 1465-1647 m above sea level. Mt. Gede Pangrango National Park is core zone of Cibodas Biosphere Reserve with high valued conservation. It representatives tropical lower mountain forest with annual rainfall 3,000-4,200 mm, temperature 10-18 °C and relative humidity 80-90 %. Forest dominated by member of Fagaceae and Theaceae tree families.

Vegetation sampling

Vegetation sampling limited only for tree (dbh >10 cm) and treelet (woody, dbh <10 cm). Edge-to-interior line transect was sampled under study at length 1,600 m and width 10 m alongside human trail. Line transect marked every 100 m to record species, measure its abundance, canopy openness, height and diameter at breast height. Basal area and species density expressed in 1,000 m². Tree and treelet were identified in the field and plant vouchers were collect for unidentified species and after that it were identify at Cibodasiense herbarium.

Analysis

Data obtained in the field was compiled and analysed for native and non-native species. Simple statistic was performed to summarize basic numerical data, such as member of families and species for both tree and treelet. Dominant species was determinate by species abundance and Important Value Index (IVI). Moreover, IVI was estimated by sum of relative density, relative frequency and relative dominancy. Shannon-Weiner diversity index (H') and evenness index (E) were calculated for each plot.

Averages of measured vegetation variables (and corresponding standard errors) were calculated for every distance class. Analysis of variance (ANOVA) used to assess statistical differrences in vegetation variables in relation to distance and thus it followed by Tukey multiple comparison tests.

RESULTS AND DISCUSSION

Results

The biological composition and biodiversity index were not differed among distance from CBG (Table 1). A plot near CBG (located at 200-300 m from botanical garden) had the highest species number (tree and treelet), family number, individual number and Shannon-Weiner diversity index (H'= 3.791±0.005) and then slightly decreased along the gradient and subsequently it were evenly distributed along transect. Non-native plant species was localized at first half of transects and only 3 plots (19 %) were free of non-native species. Most of all plots were dominance by native plant except for a plot at distance of 500-600 m from CBG which dominated by non-native species, i.e. *Cestrum aurantiacum*. *Schima wallichii*, the giant one tree species at tropical forest, was present at more than partly transect. ANOVA test resulted Shannon-Weiner diversity index (H') and evenness index (E) were not significant among plots.

Tree composition structure of study site was commonly found in the lower montane tropical rain forest. Dominant tree species was *S. wallichii*, *C. javanica*, and *V. rubescens* (Table 2). The last tree species is generally found in secondary forest. Dominant treelet family was Solanaceae followed by Urticaceae and Staphyleaceae. Treelet of Solanaceae family consists of 4 species, i.e. *Brugmansia candida*, *C. aurantiacum*, *Solanum torvum*, and *S. verbscifolium*. *C. aurantiacum* as a non-native species had the highest important value index in treelet class (IVI= 21.34).

Among the plots, plots which located relative close to CBG had the highest tree basal area (7.55 m²/1000 m²), the highest native tree density (50 tree/1000 m²) and the highest treelet density (238 treelet/1000 m²; Table 3). The nearest plot from CBG had the highest canopy openness which it means lighter can penetrate forest canopy. Tree basal area was not significantly varied across transect (ANOVA F= 0.974, P>0.05) in relation to altitude gradient. Native tree density was even distributed along plots and 50 % plots was absence from non-native tree species. None of non-native tree species was present at above 1100 m from CBG.

Table 1 Numerical summary of species richness, species composition, diversity index and evenness of study site

Distance from botanic garden (m)	Species richness	Native species	Non-native species	Family number	Tree	Treelet	Indivi-duals	Shannon-Weiner Index (H')	Evenness
0-100	51	48	3	32	21	18	178	3.512 (0.007)	0.893 (0.002)
Dominant species: *Engelhardtia spicata* Lesch. Ex Blume, *Litsea firma* (Blume) Hook. f.									
100-200	60	59	1	30	25	44	245	3.661 (0.006)	0.894 (0.001)
Dominant species: *Castanopsis javanica* A.DC., *Macropanax dispermus* Kuntze									
200-300	69	66	3	34	29	52	298	3.791(0.005)	0.895 (0.001)
Dominant species: *Acronychia* sp., *Persea rimosa* Zoll. ex Meisn.									
300-400	49	46	3	30	16	64	163	3.52 (0.007)	0.904 (0.002)
Dominant species: *Engelhardtia spicata* Lesch. Ex Blume, *Schima wallichii* (DC.) Korth.									
400-500	40	37	3	24	17	34	167	3.169 (0.009)	0.859 (0.002)
Dominant species: *Schima wallichii* (DC.) Korth., *Castanopsis javanica* A.DC.									
500-600	32	30	2	19	14	24	144	2.453 (0.014)	0.708 (0.004)
Dominant species: *Villebrunea rubescens* Blume, *Cestrum aurantiacum* Lindl.*									
600-700	27	23	4	13	16	21	183	2.495 (0.017)	0.757 (0.005)
Dominant species: *Lithocarpus indutus* Rehder, *Solanum verbascifolium* L.									
700-800	34	31	4	19	13	30	114	3.087 (0.01)	0.875 (0.003)
Dominant species: *Ficus involucrata* Lam., *Villebrunea rubescens* Blume									
800-900	35	30	4	20	19	28	131	3.147 (0.01)	0.885 (0.003)
Dominant species: *Schima wallichii* (DC.) Korth., *Castanopsis javanica* A.DC.									
900-1000	28	28	0	20	18	20	95	2.877 (0.014)	0.863 (0.004)
Dominant species: *Altingia excelsa* Noronha, *Ardisia fuliginosa* Blume									
1000-1100	26	25	1	18	16	17	79	2.809 (0.014)	0.862 (0.004)
Dominant species: *Villebrunea rubescens* Blume, *Schima wallichii* (DC.) Korth.									
1100-1200	24	24	0	17	15	15	65	2.886 (0.013)	0.908 (0.004)
Dominant species: *Castanopsis javanica* A.DC., *Schima wallichii* (DC.) Korth.									
1200-1300	28	27	1	20	19	18	87	2.899 (0.013)	0.87 (0.004)
Dominant species: *Castanopsis javanica* A.DC., *Schima wallichii* (DC.) Korth.									
1300-1400	32	31	1	19	21	21	94	3.153 (0.01)	0.91 (0.003)
Dominant species: *Manglietia glauca* Blume, *Schima wallichii* (DC.) Korth.									
1400-1500	26	25	1	16	16	18	96	2.776 (0.014)	0.852 (0.004)
Dominant species: *Schima wallichii* (DC.) Korth., *Cryptocarya ferrea* Blume									
1500-1600	23	23	0	14	16	15	71	2.816 (0.014)	0.064 (0.004)
Dominant species: *Schima wallichii* (DC.) Korth., *Saurauia pendula* Blume									
ANOVA								4.127[ns]	7.471[ns]

Note: Standard error is in parentheses. Non-native species is indicated by asterisk. ns: not significant

Table 2 Top ten tree and treelet dominant species of study site

Tree		Treelet	
Species (family)	IVI	Species (family)	IVI
Schima wallichii (DC.) Korth. (Theaceae)	31.04	*Cestrum aurantiacum* Lindl. (Solanaceae)*	21.34
Castanopsis javanica A.DC. (Fagaceae)	25.15	*Villebrunea rubescens* Blume (Urticaceae)	19.59
Villebrunea rubescens Blume (Urticaceae)	19.12	*Solanum verbascifolium* L. (Solanaceae)	15.04
Saurauia pendula Blume (Actinidiaceae)	16.47	*Turpinia sphaerocarpa* Hassk. (Staphyleaceae)	14.66
Turpinia sphaerocarpa Hassk. (Staphyleaceae)	13.43	*Ardisia fuliginosa* Blume (Myrsinaceae)	13.64
Macropanax dispermus Kuntze (Araliaceae)	13.02	*Dendrocnide stimulans* (L.f.) Chew (Urticaceae)	11.13
Persea rimosa Zoll. ex Meisn. (Lauraceae)	12.09	*Saurauia pendula* Blume (Actinidiaceae)	9.19
Castanopsis argentea A.DC. (Fagaceae)	9.55	*Magnolia liliifera* Baill. (Magnoliaceae)	8.27
Engelhardtia spicata Lesch. Ex Blume (Juglandaceae)	8.55	*Macropanax dispermus* Kuntze (Araliaceae)	8.13
Solanum verbascifolium L. (Solanaceae)	7.63	*Saurauia reinwardtiana* Blume (Actinidiaceae)	7.72

Non-native species is indicated by asterisk

In terms of treelet, it basal area was slightly decrease with the increasing of distance from CBG. However, ANOVA test was result non significance between treelet basal area and distance from botanic garden (F= 7.561, P> 0.05). Native treelet was more concentrate in a first half of transect and then decreased along the increasing of distance. Non-native treelet species was not present at 25 % plots and their density had high number at 400-1000 m from CBG.

All non-native species showed variation in density in relation to distance from edge to interior forest (Figure 1). Almost all non-native species were present near CBG except *B. Candida* and *S. macranthum*. At more than 1000 m from CBG boundary, density of non-native species was sharp decline and only 2 species were found, i.e. *A. inulifolium* and *S. macranthum*. *A. inulifolium*, an invasive alien plant species in forest disturbed area, almost present along transect. There are a ditch crossed transect at distance 650 m from forest edge and it possibly altered non-native species pattern distribution for water demanding species such as *B. candida, C. aurantiacum,* and *S. torvum.*

Table 3 Density of tree and treelet across the distance from botanic garden

Distance from botanic garden (m)	Altitude (m asl)	Canopy openness (%)	Tree basal area (m2/ 1000 m^2)	Native tree density (stems/ 1000 m^2)	Non-native tree density (stems/ 1000 m^2)	Treelet basal area (m2/ 1000 m^2)	Native treelet density (stems/ 1000 m^2)	Non-native treelet density (stems/ 1000 m^2)
0-100	1465	36.37	4.80 (0.03)	28	3 (0.33)	0.2	136	10
100-200	1476	25.52 (2.63)	7.55 (0.04)	44	1	0.22	195	4
200-300	1469	22.89 (1.57)	5.74 (0.03)	50	0	0.25	238	9
300-400	1508	19.51 (3.66)	4.81 (0.05)	29	1 (1.50)	0.17	127	5
400-500	1515	21.21 (3.40)	5.92 (0.05)	29	5	0.24	95	37
500-600	1532	17.97	3.00 (0.01)	46	10 (0.30)	0.21	50	36
600-700	1541	25.02 (3.37)	4.81 (0.05)	39	4 (0.50)	0.32	100	39
700-800	1574	19.70 (0.90)	5.15 (0.10)	25	0	0.14	66	22
800-900	1578	23.71 (3.35)	3.57 (0.03)	34	1	0.14	80	15
900-1000	1601	23.49 (0.53)	5.36 (0.11)	26	0	0.08	67	0
1000-1100	1602	28.22 (7.09)	5.69 (0.05)	31	2	0.04	45	0
1100-1200	1614	21.78 (8.48)	3.73 (0.04)	35	0	0.06	29	0
1200-1300	1637	27.15	6.98 (0.05)	42	0	0.06	43	1
1300-1400	1654	18.05 (5.23)	2.76 (0.02)	35	0	0.09	56	2
1400-1500	1670	20.55 (1.38)	2.70 (0.02)	29	0	0.08	64	2
1500-1600	1647	19.69	3.59 (0.02)	37	0	0.06	34	0
ANOVA		0.811^{ns}	0.974^{ns}		1.785^{ns}	7.561^{ns}		

Standard error is in parentheses. ANOVA was used to test significance of distance from botanic garden. ns:not -significant
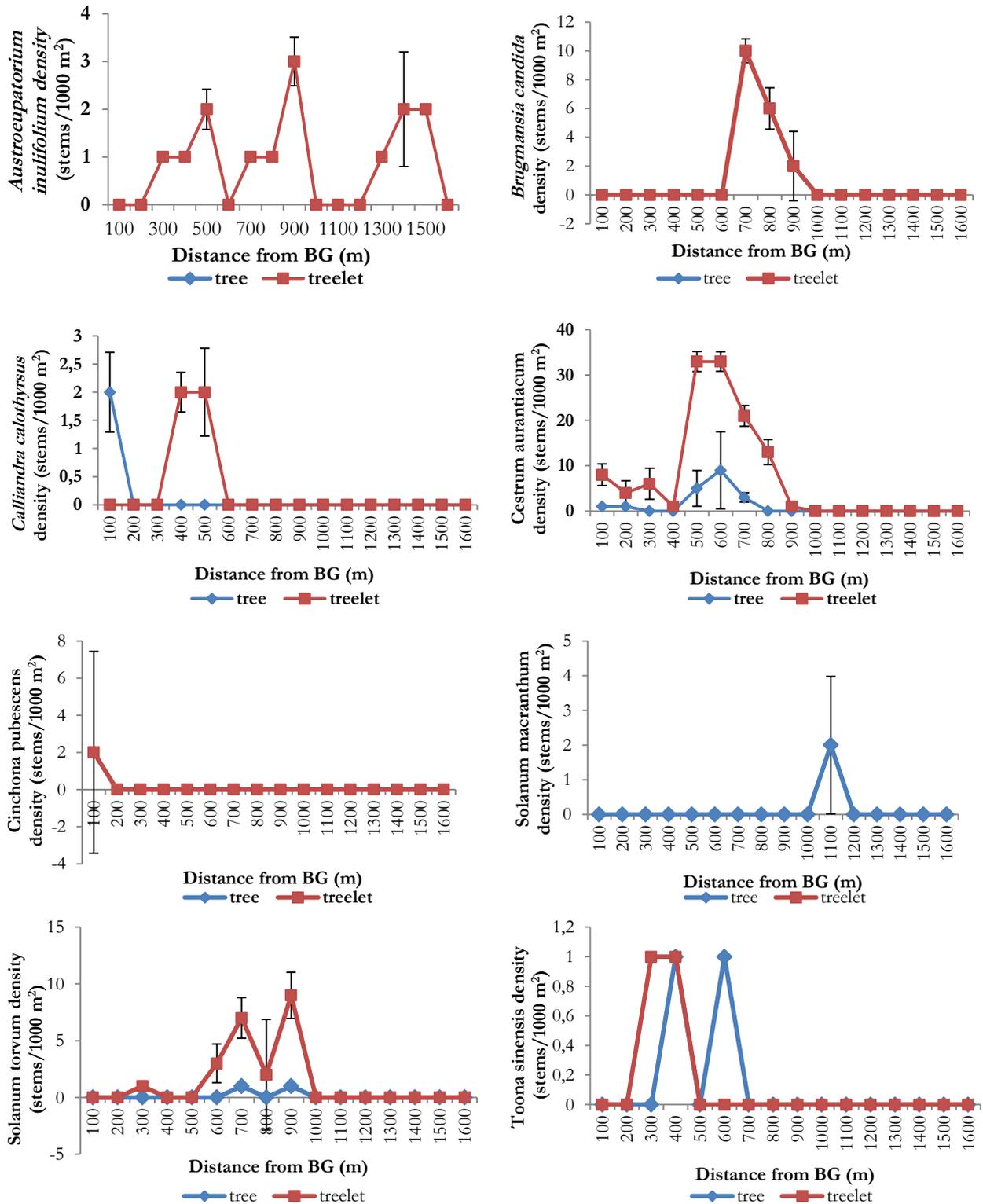
Figure 1. Density of eight non-native species in relation to transect distance from Cibodas Botanical Garden

Discussion

This study clearly demonstrates the extent to which non-native plant species from CBG invades into natural rainforest of Mt. Gede Pangrango National Park that adjacent CBG. A major limitation of this study in exploring the influence of CBG plant collection is the lack of replicate line transect. It was due to no other path across edge-to-interior forest. Opening new transect means create open gap in forest, however initiate other disturbance.

Proximity from botanical garden and forest structure on non-native species

The results showed no clear patterns related proximity to CBG in non-native species density

except for *Cinchona pubescens*, *Calliandra calothyrsus* and *C. aurantiacum*. Possibly the three species was escape from CBG to natural forest. There are no specific relations of edge-to-interior distance with decline of other six non-native species density. In addition, native tree and treelet density were show higher density near edge. Areas high in native species richness also support larger numbers of non-native species or in other words, "the rich get richer" [12]. Overall, this study indicates that CBG existence is not as a single aspect which influenced presence and abundance non-native species in natural forest.

In general, forest structure was mainly affected by impact of edge effect (Table 1 and 3). Species richness of tree and treelet tends to decrease with edge-to-interior forest. There are significant declines in species richness with distance from boundaries [13]. The vegetation pattern with distance from the edge varies with time since edge formation and also with edge physiology [14, 15]. Subsequently, edge communities are characterized by a relative high abundance of competitive and light demanding species [15].

Commonly, non-native species was found no more than 1000 m from boundary except *A. inulifolium* and *S. macranthum*. It can be caused by transect location along human trail which faciletate *A. inulifolium* spread into interior forest. *A. inulifolium* commonly found at roadsides, agricultural fields and abandoned lands [16]. Furthermore, *A. inulifolium* is reported as invasive species in Sri Lanka and in Indonesia at Alas Purwo National Park and Mt. Halimun Salak National Park [16, 17, 18] and in Mt. Gede Pangrango National Park this Asteraceae member was naturalized [19].

The three species, i.e. red quinine tree (*C. pubescens*), *C. Calothyrsus*, and orange cestrum (*C. aurantiacum*) showed edge-to-interior trend. All of three species are invasive alien species. These species were deliberate planted on garden as a plant collection. Presence of red quinine tree was related to CBG's history as a first site of red quinine tree cultivation in Indonesia at 1852 for medicinal purpose of anti-malaria [3]. *C. pubescens* is very invasive species in Galapagos and Hawaii [20, 21] by replaced native vegetation through germinated seedling around main tree [22]. *C. calothyrsus* was introduced to Indonesia for more than a half of a century for agroforestry purposes and planting around state forest land in Java [23]. This fast growing, nitro-gen fixing legume tree species was categorized as highly invasive to potential invasive [24]. There is unclear record when *C. calothyrsus* first planted but it existence at natural forest indicates it may escape from gar-

den to natural forest. *C. aurantiacum*, was introduced from Guatemala to CBG but unrecorded when it plan-ted on CBG. *C. aurantiacum* likely is a weed and the species of close relative is *C. nocturnum*, the one of aggressive introduced species was invaded Eastern Polynesian Islands.

Dispersal mode and reproductive strategies of *C. pubescens*, *C. calothyrsus*, and *C. aurantiacum* may influence the gradual spread away from CBG. Many tiny red quinine tree seeds have wings to assist their dispersal by wind [25, 26]. It also produce suckers from roots and re-sprouts readily from damage stems [3, 27]. In this study, red quinine treelet was found at around 10 m from edge. It indicates sexual reproduction of quinine constraint the spread of this species away from edge. Another species, *C. calothyrsus* is widespread species and often locally abundant in tropics. The seed dispersal of *C. calothyrsus* is explosive apical dehiscence generated by drying tensions in the pod wall [28] with number of seeds usually 8 (rarely 12) per pods [24]. Therefore, seed dispersal of *C. calothyrsus* limited spread into interior forest. Furthermore, the sexual systems of *C. calothyrsus* appear to limit the quantity of seed an individual tree can produce [24]. Many seed of *C. aurantiacum* germinated under main tree and lots of small seed dispersed by small birds. In this study, another invasive species was spread vegetatively through rhizomes i.e. square stemmed bamboo (*Chimonomambusa quadrangularis*; data not presented here).

Another driving factor for the spread of red quinine tree, *C. calothyrsus* and *C. aurantiacum* is consequence of the large of openness area at the edge. Edge area had the largest percentage of canopy openness (Table 3). It means more light reached forest floor and afterward it was support seedling growth. Invasion of *C. pubescens*, which are usually more shade-adapted, was in general reduces the cover of herbaceous species [26]. More sun was needed by *C. calothyrsus*, a light-demanding species, to support its growth [28]. Shade may enhance the likelihood of non-native species [29]. Furthermore, both *C. pubescens* and *C. callothyrsus* may release allelopathy, secondary metabolites that may adversely affect the growth of other plants [21, 30], which encourages the success of plant species in the alien environment [7, 31].

Another possible source of non-native species

A number of non-native tree and treelet species in this study was lack edge-to-interior trend in stem density. Some of them were first appeared at distance >300 m from periphery i.e. *A.*

inulifolium, *B. candida*, *S. macranthum*, *S. torvum*, and *Toonasinensis* and another had bell-shaped pattern i.e. *C. aurantiacum*. Both of *S. macranthum* and *T. sinensis* did not have general pattern of spread distribution because both species occurred at single individual at certain distances. It showed that presence of CBG's plant collection irregularly influenced spread of non-native species in natural forest.

Some of non-native species showed peak in stem density at around 600-700 m from CBG (*Figure* 1). All of them are member of Solanaceae i.e. *B. candida*, *C. aurantiacum* and *S. torvum*. Presence of a ditch crossed transect at 650 m from edge may possibly responsible for change of edge-to-interior trend. Coffee invasion study in India encountered similar trend due to the perennial stream separating forest fragment and coffee plantation, which may act as a barrier for movement of small mammals and reduce seed dispersal into interior [29]. Differ from coffee invasion study, this study indicated ditch and water puddle around it were assist accelerate increase of non-native stem density, particularly Solanaceae. Birds and bats play an important role in the distribution of Solanaceae, since these are potentially the most likely dispersers [32]. Either ditch or water puddle attracted birds and bats for visiting, favouring water consumption and in consequences seed dispersal.

Disturbed forest likely had positive correlation with non-native species density. In this study, forest structure, and species composition were estimate disturbance level under the assumption the more pristine, the less disturbed [29]. At average, decline of tree basal area was in line with Macaranga occurrence (Table 3). Presence of Macaranga, a generalist pioneer tree species, could use as an indicator for forest disturbance [33]. Disturbance (mainly man-made) favours changes in vegetation coverage and species abundance, implying microclimatic changes [32].

Another factor that may influence the lack of edge-to-interior trend in non-native species density is propagule pressure from CBG. Large numbers of propagules can result in successful invasions, even if environment is suboptimal for establishment of the species [22]. *C. aurantiacum*, a potensive invasive alien species, unclear recorded as plant collection on. It was escape from garden unintentionally through numerous germinated seedling under its canopy and a lot of minute seed which dispersed by small birds. It was presence edge-to-interior and abundance increase sharply near ditch (Figure 1).

Conservation implications

Risk posed by botanic garden collection to escape into other habitat is cannot be avoided. The increased incidence of invasion from botanical garden poses major threat to indigenous biological diversity [4]. Many assessments were developing to predict the invasiveness of introduced plant [2, 34, 35] but its applications were limited. The case study of CBG presented here highlights those botanical gardens should minimize the risk of unintentional introduced plant by perform risk assessment which site specific.

As neighbouring area of natural forest, CBG has a function as buffer zone to protect its biodiversity. The risk of plant invasions arising from CBG's collection can be diminished by (1) carry out invasive risk assessment before it planted on the garden; (2) do applied research to control invasive species from garden collection and restore natural forest that have been negatively affected by invasive alien species; and (3) create effective barrier to avoid plant invasion from CBG.

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